Los Alamos scientists propose new theory for development of turbulent magnetic reconnection

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LOS ALAMOS, New Mexico, April 15, 2011—In this week's *Nature Physics*, Los Alamos physicist Bill Daughton and a team of scientists present a new theory of how magnetic reconnection proceeds in high-temperature plasmas.

Magnetic reconnection is a fundamental process in physics, the continuous breaking and rearrangement of magnetic field lines in a plasma—a hot ionized gas. Understanding reconnection phenomena has broad implications in how Earth's magnetosphere functions, how solar flares and coronal mass ejections work—and how they might affect our planet, and a wide variety of astrophysical settings.

This new theory was developed to better explain recent large-scale three-dimensional kinetic simulations that describe the physics of this process at the most basic level.

"Previous kinetic studies have been primarily limited to simple two-dimensional models," said Daughton. "A team of researchers from across the Laboratory employed a first-principles approach to study the dynamic evolution in three dimensions using the plasma simulation code VPIC, a particle-in-cell plasma physics code."

Daughton continues, "These 3-D calculations required a thousand times more computational resources than the 2-D models. This only became possible recently due to the development of petascale supercomputers, first with Roadrunner at Los Alamos and more recently on the Kraken machine at Oak Ridge National Laboratory. Funding from the LANL Laboratory Directed Research & Development program has allowed us to exploit these powerful new machines as soon as they became available."

The *Nature Physics* article reports the new results are drastically different than the previous 2-D models and feature the formation and turbulent interaction of helical magnetic structures known as flux ropes. Early researchers speculated that such flux ropes may form during the initial development of magnetic reconnection, but the new results demonstrate that the vast majority of these structures are produced within intense electron current sheets that form at later time. The key features of this complex evolution are explained by the new theory described in this paper.

These results have important implications for spacecraft observations of magnetic reconnection in the magnetosphere and in the solar wind. Many of these new predictions should be observable by NASA's upcoming Magnetospheric Multiscale (MMS) mission—a group of four spacecraft that will make high-quality measurements of magnetic reconnection as it occurs in the magnetosphere. Los Alamos researchers were recently awarded a three-year $1.6 million grant from NASA to continue these research efforts in support of the MMS mission, which will launch in 2014.

The physics of magnetic reconnection is central to understanding the processes that control the magnetosphere, a kind of “global shield” that protects Earth from deadly cosmic radiation coming from solar flares and the solar wind.

Understanding reconnection physics may lead to better models of the near-earth space environment and the potential harmful effects to both space travelers and satellites.

“These are really dramatic large-scale simulation results,” said Daughton. “Together with theory, laboratory experiments, and new satellite observations, we believe these simulations could change some important ideas of how magnetic reconnection occurs.”

The research team includes Daughton, Vadim Roytershteyn, Lin Yin, Brian Albright, Kevin Bowers, and Ben Bergen at Los Alamos as well as Homa Karimabadi at the University of California, San Diego.